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WHEAT BREEDING FOR HIGH YIELD POTENTIAL AND DURABLE RESISTANCE AGAINST YELLOW RUST

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ABSTRACT

Breeding program for yellow rust (*Puccinia striiformis* f.sp.*tritici*) resistance was initiated at Wheat Research Institute, Faisalabad, Pakistan, during 1992-93 for the development of wheat varieties having minor gene based resistance against yellow rust. Wheat germplasm was screened for yellow rust resistance under natural and high stress inoculation conditions with diversified inoculum at several locations. The rust development pattern was observed and data was recorded for yellow rust for two years. Accessions carrying minor genes were identified based on slow rusting behavior and low terminal rust reaction. Auqab 2000, Kohistan 97, Pb 96, Shalimar 88, HD 2179, Luan and Weaver showed moderate level of resistance against yellow rust at natural hot spot areas and under artificial inoculation conditions. The local adapted varieties like Lu 26, Pak 81, MH 97, Inqilab 91, Chenab 2000 and V-87094 (Wattan) have high yield potential history. These lines were crossed by following single cross, double cross, top cross or backcross method for pyramiding minor genes for rust resistance and high yield potential. Segregating material was evaluated under artificial rust inoculation and natural conditions using selected bulk method approach. The homozygous lines having high yield potential and better resistance than the parents and the existing wheat varieties were selected in F_7 generation for the evaluation in station yield trials (A and B trials) for two years. In different ecological zones of Pakistan, these lines were also tested for yield and rust under Provincial (MICRO) & National (NUWYT) trials for one and two years respectively. The most promising crosses were Lu26/HD2179/2* Inqilab-91 (V-00183R), Shalimar-88/Weaver (V-02156), Shalimar-88/Wattan//MH-97 (V-02192), Luan/Kohistan (V-03138), Shalimar-88/V-90A204//MH-97 (V-04178), Pb-96/Wattan//MH-97 (V-04179), Chenab-2000/Inqilab-91 (V-05082),Lu-26/HD-2179//Chill'S' (V-06018), Shalimar-88/Pak-81//MH-97(V-06068), Auqab-2000 /Milan (V-6096), Oasis/5*Angra//Inqilab-91 (V-06117), and Lu26/HD2179(V-87094). Two varieties, Shafaq-06 and Lasani-08 have been released for general cultivation during years 2006 and 2008, respectively. Some other lines having better resistance than the parents are in the pipeline. Shafaq-06 and Lasani-08 have high yield potential and durable type of resistance mechanism for yellow rusts.

Keywords: Wheat, stripe rust screening, *Puccinia striiformis*, durable resistance, yield potential.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is a worldwide cultivated crop. The world production of wheat is 607 million tons, making it the third most-produced cereal after maize (784 million tons,) and rice (651 million tons), (FAO, 2007). In Pakistan, wheat is the major staple food of the people and is cultivated on an area of 9.046 million hectares with an annual production of 24.032 million tons (Anon. 2010). Many factors like rusts, drought, heat, sunlight, salinity, irrigation water etc are limiting the achievement of potential yields of the varieties. But rusts are persistent threat and have caused 10% reduction in national yield during 1978 leaf rust epidemic (Hassan 1979). During 1995, yellow rust epidemic in NWFP caused 20% yield losses Chaudhary *et al.,* 1996). Similarly huge yield losses occurred during 2005 because of worst yellow rust epidemic in NWFP and northern districts of the Punjab i.e., Attock, Rawalpindi, Chakwal, Jhelum and Sialkot (Khan *et al.,* 2005).

Yellow rust (*Puccinia striiformis* Westend. *f.sp. tritici*) can reduce wheat yields by as much as 84% (Murray *et al*., 1995). It is, therefore, of considerable economic importance to control this disease. In the last decades, around 40 race-specific yellow rust resistance genes have been identified in wheat and deployed in wheat breeding programs (McIntosh *et al*., 1995). This type of resistance can, however, be broken down due to changes in virulence of the *P. striiformis* pathogen. That may overcome the race-specific resistant genes. Virulences against major genes like Yr1, Yr2, Yr3a, Yr4a, Yr6, Yr7, Yr9, Yr17, Yr27 and Yr28 (Kisana, 2003) have been developed. As a result major wheat varieties of the world as well as Pakistan like Pak 81, Pirsabak 85, Inqilab 91 and

MH 97 became susceptible to stripe rust and had to be banned for cultivation.

The breeding strategy of relying on major genes as a source of yellow rust resistance is rapidly becoming superseded. Therefore, now a days, pathologist & breeders have sought resistance mechanism based on minor genes which is called durable rust resistance or adult plant resistance (Broers, 1989; Singh and Rajaram, 1992; Singh *et al,* 2000). This type of rust resistance mechanism is more effective for many races rather than a single one and is long lasting (Hussain *et al.,* 1998; Hussain *et al.,* 1999, Bariana *et al.,* 2001). A high level of resistance (approaching immunity) to yellow rust could be achieved by accumulating from 4 to 5 minor genes in a variety. (Singh *et al.,* 2005). However, moderate level of resistance can be achieved by accumulating 2-3 minor genes in a line (Singh *et al.,* 2005). In spite of the absence of any effective major gene, the partial resistance of varieties indicated the presence of minor genes (Hussain *et al.,* 2006). Parents having partial resistance are crossed to pyramid genes for rust resistance and yield. This resulted many wheat lines that were better in yield and disease resistance as compared to their parent (Hussain *et al.,* 2007). This, in addition, will result in diversification of wheat genotypes in terms of their resistance background, necessary to avoid rapid evolution of the rust pathogen to acquire new virulence.

Breeding for yellow rust resistant varieties is being considered the only remedy to prevent the crop from diseases as the long-term strategy. The objective of this program was to develop & screen wheat germplasm against yellow rust under natural and high stress inoculation conditions, to monitor the lines that may have minor gene based resistance and the transfer of this resistance to the susceptible but high yielding varieties through conventional hybridization for the development of wheat varieties having minor gene based resistance against yellow rust.

MATERIALS AND METHODS

Breading for yellow rust (*Puccinia striiformis* f.sp.*tritici*) resistance program was initiated at Wheat Research Institute, Faisalabad, Pakistan, during 1992-93. Wheat germplasm comprising of 140 lines was screened for yellow rust resistance under natural conditions at Islamabad, Pirsabak, Peshawar & Kaghan and under artificial inoculated conditions with diversified inoculum at Faisalabad. All the entries were sown in two rows with two meter length at thirty cm row to row distance by repeating susceptible check, Morocco, after every ten entries. The material was planted at two sowing dates with one month interval at Faisalabad to expose it for maximum period with all growth stages under rust conditions and was inoculated by mixture of yellow rust races in 2nd week of January in addition to naturally landed rust inoculum. The data for rust reaction was recorded when susceptible check was fully loaded with rust (100S). The lines showing slow rusting trend with 20-40% terminal rust rating, when Morocco (Susceptible check) was 100S, ware marked for crossing program. This slow rusting trend is most probably due to the presence of minor genes in these lines. These parents were crossed with local adapted high yielding varieties with slow rusting history to combine high yield potential and durable rust resistance against yellow rust in bread wheat. Twenty single crosses were developed during March 1995, while in the next season thirty three one-way crosses (back cross/ top cross) were developed by crossing the F_1 with either of the recurrent parent or third parent. The material was advanced by using selected bulk approach (Singh *et al.,* 2005) and disease pressure in segregating populations was created by inoculating the susceptible border rows with diverse inoculum of yellow rust. Plants having rust reactions up to 30MRMS were tagged from each cross in F_2-F_5 generations. From F_5 generation, single head rows were raised from desirable selected plants having 90-110cm plant height, 10-30 tillers/plant, compact head, 50-90 grains/head with amber color. Similarly from the F_6 head rows, selections were again made by observing the above mentioned criteria along with low terminal rust rating. The selected F_6 rows were harvested and allotted the entry number and were put in preliminary yield testing in on-station yield trials for two years. The best ones were tested in micro yield trials and national uniform yield trials in different agro-ecological regions of the country. These entries were also tested in disease screening nurseries at hot spot areas for yellow rusts (Islamabad, Pirsabak-Nowshera Peshawar & Kaghan). The data for disease resistance was recorded by following Roelf *et al*., (1992).

RESULTS AND DISCUSSION

Germplasm was evaluated for disease reaction when the susceptible check Morroco become fully loaded with disease. Disease reaction of all the entries were recorded and six local varieties/ lines known for high yield potential and having moderate level of resistance along with two exotic lines from CIMMYT with moderate level of resistance and medium yield potential were selected for gene pyramiding studies (Table 1). The varieties/lines having high yield potential are presented in Table 2. However, their resistance has broken down due to the ineffectiveness

of yellow rust major genes such as Yr9 and Yr27 etc. (Hussain *et al.*, 2006). For combining high yield potential with minor genes based resistance against yellow rust, the single crosses, backcrosses and top crosses were developed and evaluated in the field. From these crosses, 140 lines were selected when they achieved desirable level of homozygosity and were tested in station yield trials for two years. The best performing lines selected from station yield trials were promoted to Micro Wheat Yield Trials and National Uniform Wheat Yield Trials.

It is also evident from Table 3 that Lu26/HD2179/2* Inqilab-91 (V-00183R), Shalimar-88/ Weaver (V-02156), Shalimar-88/Wattan//MH-97 (V-02192), Luan/ Kohistan (V-03138), Shalimar-88/V-90A204// MH-97 (V-04178), Pb-96/Wattan//MH-97 (V-04179), Chenab-2000/ Inqilab-91 (V-05082),Lu-26/HD-2179//Chill'S' (V-06018),Shalimar-88/Pak-81//MH-97(V-06068), Auqab-2000/Milan (V-06096) and Oasis/5*Angra// Inqilab-91 (V-06117) were the best crosses having moderate level of yellow rust resistance. These crosses produced lines which are superior in yield and disease resistance than the mega variety of Pakistan, Inqilab 91 and Seher 06. Among the best crosses Wattan, Shalimar 88 and M.H. 97 were common parents in 4 crosses each. Therefore these are best parents for the breeding programs aiming at the development of high yielding varieties having good rust resistance. The yellow rust resistance in Lasani-08 may be due to some genes present in its parents. Luan, the important parent which have an alien species among its parentage, may also be carrying minor genes for yellow rust resistance.

Table 1: Disease reactions of the selected slow rusting parents

Varieties/Lines	**Disease Reactions**					**Av.Yield Kg ha^{-1}**
	Yellow Rust					
	1992-93	**1993-94**	**2004-05**	**2005-06**	**2008-09**	
Auqab-2000	30M	30M	20MRMS	30MRMS	10MR	4000-4500
Kohistan-97	10 MR	20 MR	20MR	10MR	0	3500-4000
Luan	5MR	10MR	10MR	5MR	0	3000-3500
Shalimar-88	10MR	20MR	20RMR	30MRMS	0	4000
Punjab-96	10RMR	10MR	30MRMS	30MRMS	0	4000-4500
Weaver	10M	10MR	10MR	5MR	0	3000-3500
HD-2179	5MRMS	5MRMS	5MRMS	5MRMS	5MS	3000-3500
Morroco (Susceptible Check)	100S	100S	100S	100S	100S	-

Table 2: Disease reactions of the selected high yielding parents

Varieties/Lines	**Disease Reactions**					**Av.Yield Kg ha^{-1}**
	Yellow Rust					
	1992-93	**1993-94**	**2004-05**	**2005-06**	**2008-09**	
Inqilab-91	30M	30M	100S	30MRMS	60S	4000-4500
V-87094(Wattan)	40M	30MR	40MS	30MS	20MRMS	3500-4000
M.H-97	30MRMS	30MRMS	80S	40MSS	60S	4000
Lu 26	10MR	20MR	80S	70S	40S	4000
Pak 81	10RMR	10MR	100S	90S	100S	4000-4500
Chenab 2000	10M	10MR	60S	50S	60S	3000
Morroco (Susceptible Check)	100S	100S	100S	100S	80S	-

Table 3: Yield performance of selected durable rust resistant elite lines

Line	Parentage	Cross type	trials	Testing years	Av. Yield Kg ha^{-1}	Check Inqilab	%inc./dec Over check
V-00183R (Shafaq-06)	Lu26/HD2179//2* Inq-91	Back Cross	120	5	4139	4031*	+2.70
V-02192	SH88/V87094//MH97	Top Cross	124	5	4049	3970*	+2.44
V-02156	SH-88/Weaver	Single Cross	50	4	4236	4046*	+4.5
V -03138 (Lasani-08)	Luan/Koh.97	Single Cross	125	3	4141	3983*	+ 3.96
V-04178	SH88/90204//MH97	Top Cross	120	5	4098	4198**	+2.38
V-04179	Pb96/V87094//MH97	Top Cross	50	3	5267	5255*	+4.7
V-05082	CHENAB2000/INQ91	Single Cross	24	4	4296	4198**	+2.33
V-06018	LU26/HD2179//CHILL' S'	Top Cross	24	3	4752	4532**	+4.85
V-06068	SH88/PAK81//MH97	Top Cross	24	3	4454	4532**	+2.91
V-06096	UQAB2000/MILAN	Single Cross	24	3	4822	4532**	+6.40
V-06117	OASIS/5*ANGRA//INQ 91	Double Cross	24	3	4736	4532**	+4.50

*Inqilab, 91 **Seher 06

Table 4: Potential rust reactions of finally selected elite lines at hot spots.

Line	Parentage	Yellow rust				
		Faisalabad	Bahawal pur	Peshawar	Islamabad	Pirsabak
V-00183R (Shafaq-06)	V87094/2* Inq-91	0	0	10MRMS	20MRMS	30MRMS
V-02192	SH88/V87094//MH97	0	0	0	10R	5RMR
V-02156	SH-88/Weaver				10RMR	20RMR
V-04178	SH88/90A204//MH97	0	0	0	TMRMS	TMRMS
V-04179	Pb96/V87094//MH97	0	0	0	10R	40RMR
V -03138 (Lasani-08)	Luan/Koh.97	0	0	0	5R	15MR
V-05082	CHENAB2000/INQ91	0	0	0	TMR	TMR
V-06018	LU26/HD2179//CHILL'S	0	0	0	20MRMS	5MR
V-06068	SH88/PAK81//MH97	0	0	0	20MS	5MR
V-06096	UQAB2000/MILAN	0	0	10MRMS	20MRMS	10MS
V-06117	OASIS/5*ANGRA//INQ91	0	0	TMRMS	TMRMS	5MS
Inqilab 91	WL711/CROW	30MRMS	0	40MRMS	60S	80S
Morrocco (Susceptible Check)	-	30MRMS	0	90S	100S	100SN

Table 5: Quality parameters of the new lines / varieties

Line	1000 grain weight (g)	Chapati quality	Protein %age
V-00183R (Shafaq-06)	55	Very good	13.0
V-02192	45	Fairly good	11.0
V-02156	48	Good	12.5
V-04178	49	Good	12.12
V-04179	48	Good	13.0
V -03138 (Lasani-08)	44	Very good	12.5
V-05082	45	Good	13.60
V-06018	45	Good	13.10
V-06068	50	Good	13.23
V-06096	45	Good	13.23
V-06117	55	Good	13.30
Inqilab-91	45	Good	12.5

The advance lines presented in table-3 were tested in a series of replicated trials at various locations across the country and were compared with high yielding variety Inqilab 91, which at one time covered more than 60% of the wheat area in the country and another high yielding variety Seher 06 which is being considered as the replacement of Inqilab 91.

The line V-00183R was tested in 120 trials and it yielded 2.70% higher than the high yielding check, Inqilab 91. The line V-03138 was also tested in 125 trials and was found 3.96% high yielding as compared to the check, Inqilab 91. The line, V-02192 had shown 2.44% higher yield as compared to Inqilab 91. The other lines, V-02156, V-04178, V-04179 , V-05082, V-06018, V-06068, V-06096, V-06117 and are passing through the testing phase and have shown 4.5,2.38,4.7,2.33,4.85,2.91,6.40 and 4.5% higher yield than the check, Seher 06 (table 3). Inqilab 91 was considered as the highest yielding variety and was the most popular variety in wheat growing areas of Pakistan. Seher 06 was another high yielding variety having wider adaptability. These selected lines yielded higher than the Inqilab 91 and Seher 06 due to accumulation of genes in these lines which improved their yield potential. The development of high yielding wheat varieties by using single cross, backcross or top cross approach have been advocated by many researches. (Hussain *et al.,* 2007, Singh *et al*., 2005)

The basic objective of the study was the accumulation of minor genes for yellow rust resistance, as by crossing partially resistant parents, more minor genes can be accumulated in the lines and resistance level near to immunity can be achieved. Singh and Rajaram, 1992; Singh *et al.,* 2000 and Hussain *et al.,* 2006 have successfully accumulated minor genes for rust resistance by crossing partially resistant parents. Singh *et al.,* (2005) showed that by accumulating 4 to 5 minor genes rust reaction near to immunity can be achieved and good reaction i.e. moderate level of resistance (30-40MRMS) can be achieved by accumulation of 2-3 minor genes. The selected elite lines were tested for yellow rust in disease screening nurseries at hot spot areas (Islamabad, Pirsabak-Nowshera Peshawar & Kaghan) of Pakistan (table 4). The lines V-02192, V-04178, V-05082 and V-06117 have shown rust reactions near to immunity for yellow rust which is an indication of the presence of 3 to 4 minor genes that confer resistance to yellow rusts. Moreover, these lines are high tillering with more yield potential than all the existing wheat varieties of Pakistan. V-03138 (Lasani-08) also showed rust reactions near to immunity for yellow rusts (table 3), The rust reactions of rest of the entries i.e. V-00183R, V-02156, V-04179, V-06018 and V-06068 is presumed to be due to the presence of 2-3 minor genes for resistance against yellow rust. However, assessment of the minor genes accumulated in these lines should be confirmed by conducting genetic studies.

These lines were also tested for grain quality parameters (table 5). All the selected lines showed better 1000-grain weight ranging from 44 g to 55 g. The lines V-00183R and V-06117 showed maximum

grain weight i.e. 55 g. The line V-00183R showed better grain weight (55 g), protein percentage (13%) and its bread (chapatti) quality was very good. Similarly V 03138 also showed good grain weight (44 g), protein level (12.5%) and very good bread (chapatti) quality.

The line V-00183R was released in 2006 as Shafaq-06 for general cultivation and is gaining popularity among the farming community due to its higher yield and very good Bread (chapatti) quality characters. Similarly V-03138 was released as Lasani-08, in the year 2008. During its first year of cultivation at farmer's fields its yield performance was excellent.V-04178 has completed all the provincial and national trials and is ready for approval as rust resistant commercial wheat variety in Pakistan.

Hopefully, it will also be a popular variety due to its higher yield, good quality characteristics and desirable level of rust resistance against all the three rusts. It is also a good choice for the stem rust prone areas.

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